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New Nuclear Imaging Techniques and Clinical Applications

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Mini Review

Nuclear medicine is known as one of the most mature molecular imaging techniques [1]. From single photon emission computed tomography (SPECT) to positron emission tomography (PET) and from single modality imaging to dual even multi-modality imaging, namely fusion imaging, such as SPECT/CT, PET/CT and PET/MRI, imaging techniques of nuclear medicine are growing so rapidly in recent years. We summarize the current state of nuclear imaging techniques developments and clinical applications in kinds of diseases, particularly cancers here.

SPECT has dominated the list of nuclear imaging for more than 30years for its wide availability of cameras and radio pharmaceuticals. With the first commercial SPECT/CT (a dual-headed sodium iodide crystal gamma camera with a gantry incorporating an x-ray tube with fan-beam technology that enabled low-dose CT at a maximum tube current of 2.5mA) was available in 1999 (GE Healthcare) [2], this instrument, which fused function mapping with accurate structure data, has many established and potential clinical value, especially in oncology. The clinical application of SPECT/CT in 2 slices, 6 slices or over 16 multi-slice spiral CT scan is widely used [3]. Elevating diagnostic sensitivity (superior disease localization) and specificity (exclusion of false-positives due to physiological tracer uptake) [4], it plays a key role in the diagnosis, staging, treatment, and monitoring of different kinds of tumors, such as neuro endocrine tumors (NET), thyroid tumors, lymphoma, sentinel node, indeterminate bone lesions and other carcinomas.

The potential future clinical impact of SPECT/CT depends on two fields, i.e. instruments and radiopharmaceuticals. The continued advances in the equipments will concentrate on scanning speed, radiation exposure and new computer software technology for image scanning, analyzing and displaying. With tissues-specific molecular probes developing and even practicing in patients, the role of molecular imaging with SPECT/CT willen large in precision medicine in future. Recent years SPECT has fainted as its limitations, for example low resolution and time consuming, as a result scholars chronically switched their attentions to the preponderances of hybrid positron emission tomography/computed tomography(PET/CT) in oncology rather than the clinical utility of SPECT or SPECT/CT.

As one of the most rapidly developing fields in medical imaging, PET which visualizes, characterizes, and measures biological processes at the molecular levels with a noninvasive method has established a series of applications in the management of patients with kinds of disorders, especially cancers [5].

Like SPECT/CT, the development of PET/CT scanner concentrates on reducing scanning time and radiation exposure, furthermore, manufactures focus on advanced computer-based methods for data analysis and display at the same time [6]. By coincidence detection and pinhole collimation, PET can precisely locate the source of the annihilation event with better resolution than that of SPECT. Most of clinical researches have evidenced that Time-of-Fly PET (TOF-PET) significantly improved imaging quality and simultaneously reduced radio activity (>50% at least) [7]. Patient motion in PET is a source of error due to possible mismatches between the PET data and the CT attenuation map (μ-map), Bousse et al developed a motion compensated reconstruction scheme for gated PET data, namely joint reconstruction/motion estimation (JRM), to jointly estimate both the activity distribution and the motion field, by penalized likelihood maximization. But JRM needs a high numberof iteration due to the significant cross-talk in the joint-likelihood. TOF-PET for JRM demonstrated that the convergence speed is significantly improved compared to JRM with conventional PET data [8].

Beyond what described above, radiopharmaceuticals plays a key role in nuclear imaging, including PET/CT. Radiopharmaceuticals has two parts: radionuclide and pharmaceuticals. Many positron emitting radio nuclides has been successfully labeled to PET probes for research and clinical application. Several metallic isotopes are available in small biomedical cyclotrons or generators nowadays. For example, a

[6-8] Ga (Emax 1.90MeV, $T_{1/2}$ 68.1 minutes) generator provides an opportunity to prepare PET radio pharmaceuticals anywhere in need. ^{64}Cu (Emax 657keV, $T_{1/2}$ 12.7 hour) and ^{124}I (Emax 2.13MeV; 1.53MeV; 808keV, $T_{1/2}$ 4.2 days) are suitable for labeling peptides or proteins. Among non metallic isotopes, ^{18}F (Emax 635keV, $T_{1/2}$ 109.8 minutes) has been widely used all over the world, what's more, 11C (Emax970keV, $T_{1/2}$ 20.4 minutes) is an attractive labeling positron-emitting isotope. A diverse array of reactions for ^{11}Clabeling molecules has been in researching and developing. The other functional part of radiopharmaceuticals includes small molecular, amino acid, peptide, protein and McAb, such as FDG, choline, FLT, estradiol, RGD, RRL, TOC/NOC/TATE, PSMA and so on, which can attach to specific molecular at different tissues.

As a promising multi-modality imaging technique, Positron emission tomography/magnetic resonance imaging (PET/MRI) which simultaneously acquires morphologic, metabolic and functional mappings (DWIorPWI) with excellent soft tissue resolution has emerging in the assessment of response to treatment in neuropathy, oncology and the detection of distant metastases [9]. What's more, the preliminary studies suggest that simultaneous ^{18}F-FDG and dynamic-contrast enhanced MRI (DCE MRI) may aid in the assessment of tumor aggressiveness and metastatic potential [10]. Scholars place hopes on PET/MR shows some significant advantages over PET/CT e.g. in head and neck cancer evaluation or liver metastases detection [11]. Scientists has turned to explore multi-targeting/multi-modality probes which can be used to directly detect diseases in living human body and open up new strategy from different aspects at present.

It is essential to explore and establish the appropriate systems such as multiple models of varies nuclear imaging techniques of malignancies [12], which would take full advantages of those molecular imaging of nuclear medicine in precision medicine practice, and patients would benefit from our efforts eventually.

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